PROCEDURE FOR DETERMINING HEATING AND COOLING LOADS FOR COMPUTERIZED ENERGY CALCULATIONS

ALGORITHMS FOR BUILDING HEAT TRANSFER SUBROUTINES

Compiled and published by
The Task Group on Energy Requirements for Heating and Cooling
AMERICAN SOCIETY OF HEATING, REFRIGERATING AND AIR-CONDITIONING ENGINEERS, INC.

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INFIL

An Algorithm for Infiltration Rate Calculations

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INPUT:

Outdoor Conditions:

V: Wind velocity as given by the Weather Bureau or measured at the site at a 40 foot elevation, knots (Output of CLIMATE)

DIR: Wind direction angle in clockwise from north, degrees (Output of CLIMATE)

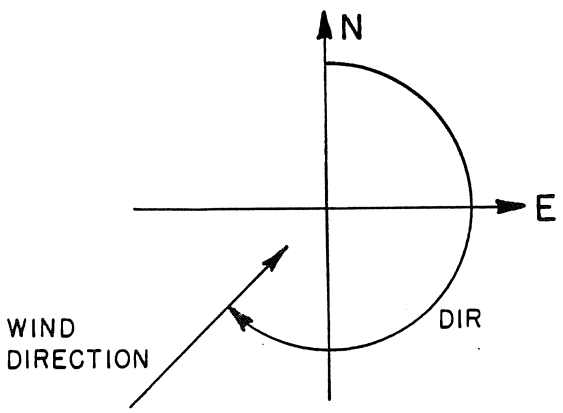

Figure 7 DEFINITION OF WIND DIRECTION ANGLE

DB: Outside air dry-bulb temperature, F (Output of CLIMATE)

PB: Barometric pressure, in. Hg (Output of CLIMATE)

Building Description:

$(HT)_k$: Height of k^{th} floor of building (from above-grade), ft

$(CFH_{Supply})_k$: Ventilation air Supplied to k^{th} floor, CFH

$(CFH_{Exhaust})_k$: Ventilation air Exhausted from k^{th} floor, CFH

HTT: Total height of building (from above-grade), ft

NF: Number of above-grade floors

NZB: Neutral zone of building, ft

If building has stairways, elevator shafts, or service shafts extending the full height of the building,

$$NZB = HTT/2$$

If building is separated,

$$(NZB)_k = (HT)_k/2$$

NZS: Neutral zone of elevator and service shaft, ft

TZ: Indoor air dry-bulb temperature, F

TS: Elevator and service shaft temperature, F

WA': Direction measured clockwise from north to normal of exterior wall surface, degrees

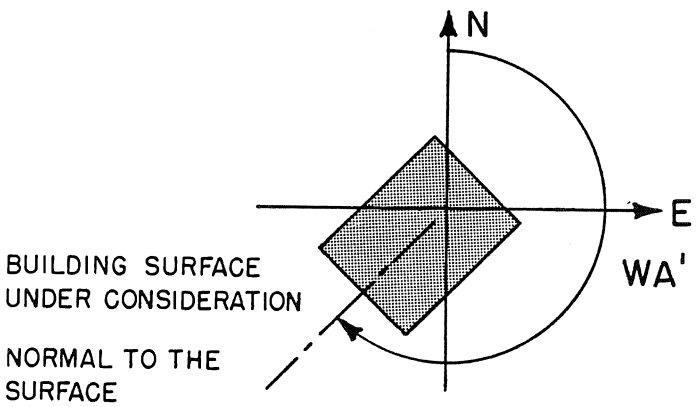

Figure 8 DEFINITION OF THE ANGLE BETWEEN NORTH AND NORMAL OF THE SURFACE UNDER CONSIDERATION

Windows and Doors:

NY: Number of windows

LY: Crack length of each window, ft

TY: Type of window

$$TY = \begin{cases} 1 & \text{Wood double-hung window (locked), non-weatherstripped, loose fit} \\ 2 & \text{Wood double-hung window (locked), non-weatherstripped, average fit} \\ 3 & \text{Wood double-hung window (locked), weatherstripped, loose fit} \\ 4 & \text{Wood double-hung window (locked), weatherstripped, average fit} \end{cases}$$

LF: Crack length of frame, ft

TF: Type of frame

TF = { 1 Around window frame is masonry wall, with no caulking
     { 2 Around window frame is masonry wall, caulked
     { 3 Around window frame is wood frame wall

ND: Number of doors

LD: Crack length of door, ft

TD: Type of door

TD = { 1 Infrequently used swinging door, 1/2" crack
     { 2 Infrequently used swinging door, 1/4" crack
     { 3 Infrequently used swinging door, 1/8" crack

INF: Flow through opening, CFH per ft crack length
Using the values given in Table 14, INF may be calculated with the following formula.

INF = CW * (DP**N)

where DP: Pressure difference across opening, in. H_2O

CW: Equivalent crack opening

N: Flow exponent

TABLE 14 FLOW CHARACTERISTICS OF OPENINGS (Table 2, p. 409, 1967 ASHRAE Handbook of Fundamentals)

TYPE	CW	N
TY = 1	357.00	0.666
TY = 2	127.00	0.666
TY = 3	128.00	0.666
TY = 4	66.00	0.666
TF = 1	75.50	0.666
TF = 2	12.80	0.666
TF = 3	64.50	0.666
TD = 1	2.67	0.500
TD = 2	1.33	0.500
TD = 3	0.66	0.500

Outside Walls:

AW: Area of wall, sq ft

TW: Type of wall

TW =
- 1 8" plain brick wall
- 2 8" brick wall and plaster
- 3 13" plain brick wall
- 4 13" brick wall and plaster
- 5 13" brick wall, furring, lath, and plaster
- 6 frame wall, lath and plaster
- 7 24" shingles on 1" x 6" boards on 14" center
- 8 16" shingles on 1" x 4" boards on 5" center
- 9 24" shingles on shiplap
- 10 16" shingles on shiplap
- 11 building paper applied between sheathing and shingles

WALEAK: Flow through wall, CFH
Using the values given in Table 15, WALEAK may be calculated with the following formula.

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WALEAK = C*AW*NWKSP*(DP**N)
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where NWKSP: Workmanship index

NWKSP =
- 0.33 good
- 1.0 poor

TABLE 15 INFILTRATION CHARACTERISTICS THROUGH WALLS (Table 3 and Figure 4, p. 410, 1967 ASHRAE Handbook of Fundamentals)

TYPE	C	N
TW = 1	59.000	.81
TW = 2	0.570	.81
TW = 3	50.000	.79
TW = 4	0.210	.71
TW = 5	0.192	.90
TW = 6	0.565	.62
TW = 7	550.000	.69
TW = 8	309.000	.69
TW = 9	219.000	.73
TW = 10	84.700	.74
TW = 11	5.000	1.00

Swinging Doors :

NDS: Number of same type swinging door entrances

NTYPE: Type of entrance

$$NTYPE = \begin{cases} 0 & \text{single-bank type} \\ 1 & \text{vestibule type} \end{cases}$$

TRT: Number of persons per hour per door

If NTYPE = 1

KD = 0.0205 + 2.66*(10**(-4))*TRT - 1.31*(10**(-7))*(TRT**2)

(If KD < 0, assume KD = 0)

If NTYPE = 0

KD = 0.00122*(TRT**0.75)

SWINGD: Swinging door entrance infiltration, CFH

SWINGD = 8300*60*NDS*KD*(DP**0.5)

Surrounding Buildings:

TB: Type of surrounding buildings

$$TB = \begin{cases} 1 & \text{Shorter building on windward side} \\ 2 & \text{Building of equal or greater height on windward side} \\ 3 & \text{Taller building on leeward side} \end{cases}$$

NSB: Ratio of distance between buildings and width of conditioned building in direction of wind

Interior Separations:

CF: Equivalent opening of stairway door, sq ft

CS: Equivalent opening of elevator doors and service shafts, sq ft

TM: Type of opening in stairway door[34]

TE: Type of opening in elevator doors and service shafts

Using the data given in windows and doors input and Table 14, CF and CS may be calculated with the following formulas.

$$CF = \begin{cases} CW * LY * NY * 2.0 \\ CW * LY * NY * 1.0 \\ CW * LY * NY * 4.0 \\ 20.0 \end{cases} \qquad \text{for TM} = \begin{cases} 1 & \text{normal fit} \\ 2 & \text{tight fit} \\ 3 & \text{loose fit} \\ 4 & \text{open stairway} \end{cases}$$

$$CS = \begin{cases} CS = CW * LY * NY * 2.0 \\ CS = CW * LY * NY * 1.0 \\ CS = CW * LY * NY * 4.0 \end{cases} \qquad \text{for TE} = \begin{cases} 1 & \text{normal fit} \\ 2 & \text{tight fit} \\ 3 & \text{loose fit} \end{cases}$$

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OUTPUT:

LEAK: Infiltration through each exposure, CFH

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CALCULATION SEQUENCE:

1. Let V' = 1.153 * V

   TO = 460 + DB

   TI = 460 + TZ

   PO = 2.036 * PB

   x = DIR - WA'

2. Calculate the wind velocity, VH, at height HT on the building, mph[35].

   VH = V' * 0.117 * (1 + 2.81 * Log (0.305 * HT + 4.75))

3. Calculate the theoretical wind velocity pressure, PTWV, at height HT, on the building, in. H_2O

   PTWV = 0.000482 * ((VH ** 2)

4. Calculate the wind direction, BWD, relative to building surfaces.

   BWD = 1 surface on windward side if,

   $-45° < x < +45°$

   BWD = 2 surface on leeward side if,

   $90° < x < 270°$

   or, $-90° < x < -270°$

BWD = 3 surface on side if,

$45° < x < 90°$

or, $-45° < x < 90°$

5. Using Table 16, determine the normal wind velocity pressure correction factor, PTKN.

TABLE 16 VALUES OF PTKN

	TB = 1			TB = 2			TB = 3		
NSB	BWD=1	BWD=2	BWD=3	BWD=1	BWD=2	BWD=3	BWD=1	BWD=2	BWD=3
0.5	.1	-.3	-.8	-.5	-.25	-.45	.5	.45	.45
1.0	-.1	-.25	-.5	-.5	-.2	-.3	.45	.3	.3
2.0	.1	-.25	-.4	.0	-.2	-.3	.45	.1	.1
3.0	.1	-.25	-.4	.1	-.2	-.35	.45	.0	.0
5.0	.25	-.35	-.6	.25	-.25	-.45	.5	-.1	-.1
∞	.6	-.35	-.7	.6	-.35	-.7	.6	-.35	-.7

6. Determine the wind velocity pressure correction factor, PTKO, for winds obliquely to the wall surface.

If BWD = 1 (windward side of building)

$(PTKO)_m = \text{Cos}\ (\ |x|\ )$

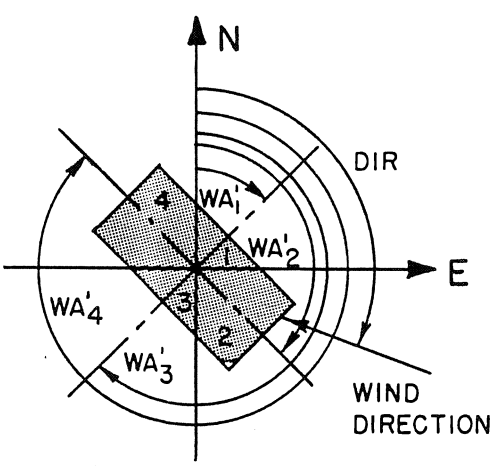
If BWD = 2 (leeward side of building)

$(PTKO)_l = 1.0$

If BWD = 3 (side of building)

$(PTKO)_s = \text{Cos}\ (\ |x|\ )$

Example:



DIR = 110°

WA'_1 = 45°

WA'_2 = 135°

WA'_3 = 225°

WA'_4 = 315°

Figure 9 DIR AND WA'ANGLES OF EXAMPLE

Side 1, $x = 110° - 45° = 65°$ (therefore, BWD = 3)

Side 2, $x = 110° - 135° = -25°$ (therefore, BWD = 1)

Side 3, $x = 110° - 225° = 115°$ (therefore, BWD = 2)

Side 4, $x = 110° - 205° = -205°$ (therefore, BWD = 2)

Side 1, $(PTKO)_s = \text{Cos}\ (65°)$

Side 2, $(PTKO)_m = \text{Cos}\ (25°)$

Side 3, $(PTKO)_1 = 1.0$

Side 4, $(PTKO)_1 = 1.0$

7. Calculate the actual wind pressure on the outside of the building, PAWV, corresponding to floor k at height HT, in. H_2O.

   $(PAWV)_k = (PTKO)_k * (PTKN)_k * (PTWV)_k$

8. Calculate the stack effect pressure on the outside of the building, PSE, corresponding to floor k at height HT, in. H_2O.

   $(PSE)_k = 0.52 * PO * ((NZB)_k - HT))/TO$

9. Calculate the total pressure on the outside of the building, PCO, corresponding to floor k at height HT, in. H_2O.

   $(PCO)_k = (PAWV)_k + (PSE)_k$

10. Calculate the pressure in the elevator and service shafts, PES, corresponding to floor k at height HT, in. H_2O.

    $(PES)_k = 0.52 * PO * ((NZS)_k - HT))/TS$

11. Calculate the pressure difference across various openings.

    a) Sum air flows for each floor

$$\sum_{x=1}^{n} ((INF)_{k,x}*(NY)_{k,x}$$

$$+ (INF)_{k,x}*(LF)_{k,x}*(NY)_{k,x}$$

$$+ (INF)_{k,x}*(LD)_{k,x}*(ND)_{k,x}$$

$$+ (WALEAK)_{k,x} + (SWINGD)_{k,x})$$

$$+ (CFH_{supply})_k - (CFH_{exhaust})_k$$

$$+ (((PES)_k - (PI)_k)**N)*(CS)_k$$

$$+ (((PI)_{k+1} - (PI)_k)**N)*(CF)_{k+1}$$

$$+ (((PI)_{k-1} - (PI)_k)**N)*(CF)_k = 0$$

where $(PI)_k$: Interior Pressure at floor k, in. H_2O

x: Number of sides of building

b) Solve[36] one set of n simultaneous non-linear equations for the values of the interior pressures $(PI)_1 \ldots (PI)_n$.

12. Calculate infiltration through window, cracks, frame cracs, doors, walls, and swinging doors with the following equations.

INFILTRATION THROUGH WINDOW CRACK:

$$(LEAKY)_{k,x} = (INF)_{k,x}*(LY)_{k,x}*(NY)_{k,x}$$

INFILTRATION THROUGH FRAME CRACK:

$$(LEAKF)_{k,x} = (INF)_{k,x}*(LF)_{k,x}*(NY)_{k,x}$$

INFILTRATION THROUGH DOORS:

$$(LEAKD)_{k,x} = (INF)_{k,x}*(LD)_{k,x}*(ND)_{k,x}$$

INFILTRATION THROUGH WALLS:

$$(WALEAK)_{k,x} = (((PCO)_{k,x} - (PI)_{k})**N)*(C)_{k,x}*(AW)_{k,x}*NWKSP$$

INFILTRATION THROUGH SWINGING DOORS:

$$(SWINGD)_{k,x} = (((PCO)_{k,x} - (PI)_{k})**0.5)*4.98*(10**5)*(NDS)_{k,x}*(KD)_{k,x}$$